

March 1, 2012



# Office of Electricity Delivery & Energy Reliability



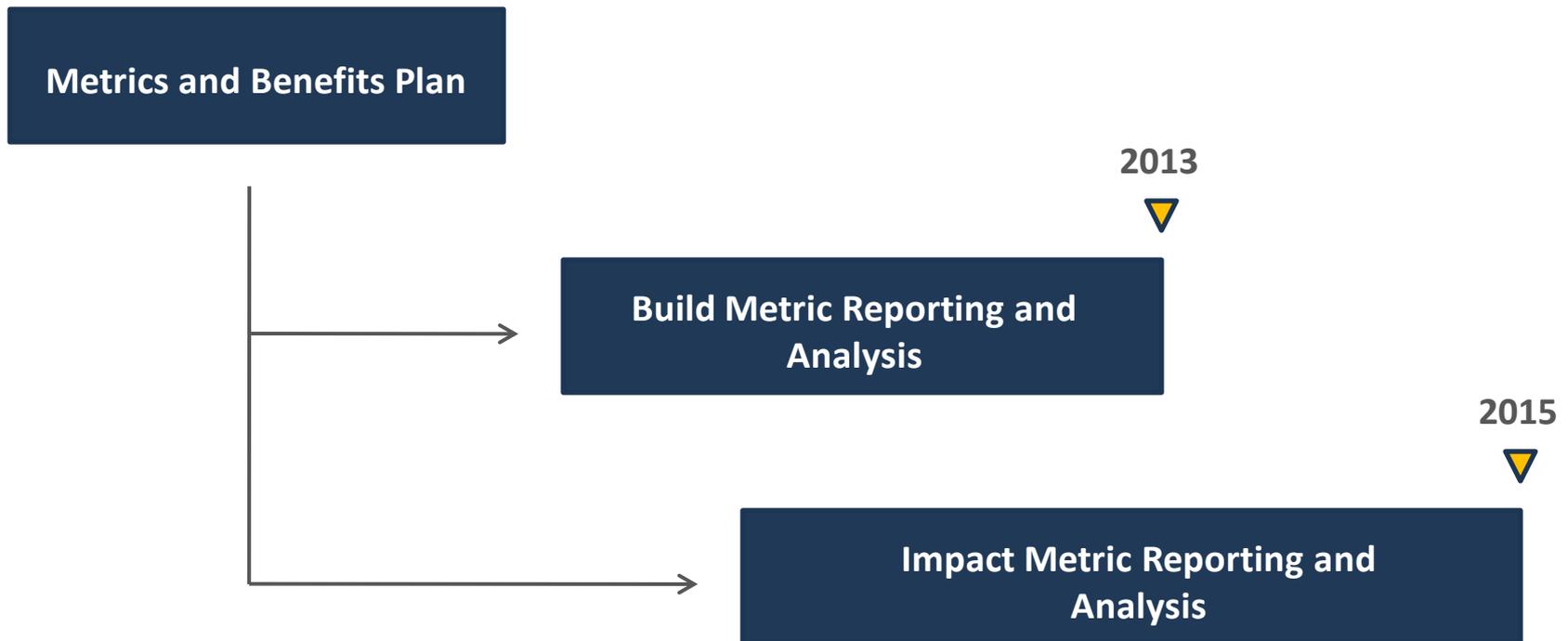
## Energy Efficiency in Distribution Systems

## DOE Analysis Approach



# Introduction

Build and impact metric data provided by the SGIG recipients convey the type and extent of technology deployment, as well as its effect on grid operations and system efficiency.





# Six Primary Analysis Focus Areas

There are six areas where the analysis is focused. This presentation addresses analysis efforts associated with energy efficiency in distribution systems.

## Peak Demand and Electricity Consumption

- Advanced Metering Infrastructure
- Pricing Programs and Customer Devices
- Direct Load Control

## Operations and Maintenance Savings from Advanced Metering

- Meter Reading
- Service changes
- Outage management

## Distribution System Reliability

- Feeder switching
- Monitoring and health sensors

## Energy Efficiency in Distribution Systems

- Voltage optimization
- Conservation voltage reduction
- Line losses

## Operations and Maintenance Savings from Distribution Automation

- Automated and remote operations
- Operational Efficiency

## Transmission System Operations and Reliability

- Application of synchrophasor technology for wide area monitoring, visualization and control



# DOE/Recipient Dialogue

DOE would like to establish a dialogue with recipients to explore energy efficiency in distribution systems associated with the application of equipment to perform voltage optimization and control. The outcome is to share this information across the industry.

## DOE's Interests

1. **Analysis Approach: Working through issues relating to measuring impacts**
  - a. Analytical methodology
  - b. Baseline/control groups
  - c. Underlying factors leading to results
  - d. How to convey the results and to whom?
2. **Lessons-Learned/Best-Practices: Internally and externally conveyed**
  - a. What can we learn from each other?
  - b. How do we want to document lessons-learned and best practices for external communication?
  - c. Are there detailed case studies that can be developed?

## Recipients' Interests

1. What would you like to address in a group setting?
2. What do you want to learn or share?
3. How would you like to exchange information?
  - a. In smaller or more focused groups?
  - b. How should we structure and support the discussion?
4. Are there issues you are NOT interested in addressing here?



# DOE's Analysis Objectives

This focus area will examine improvements energy efficiency and decreases in line losses from the application of technology to perform voltage optimization and conservation voltage reduction.

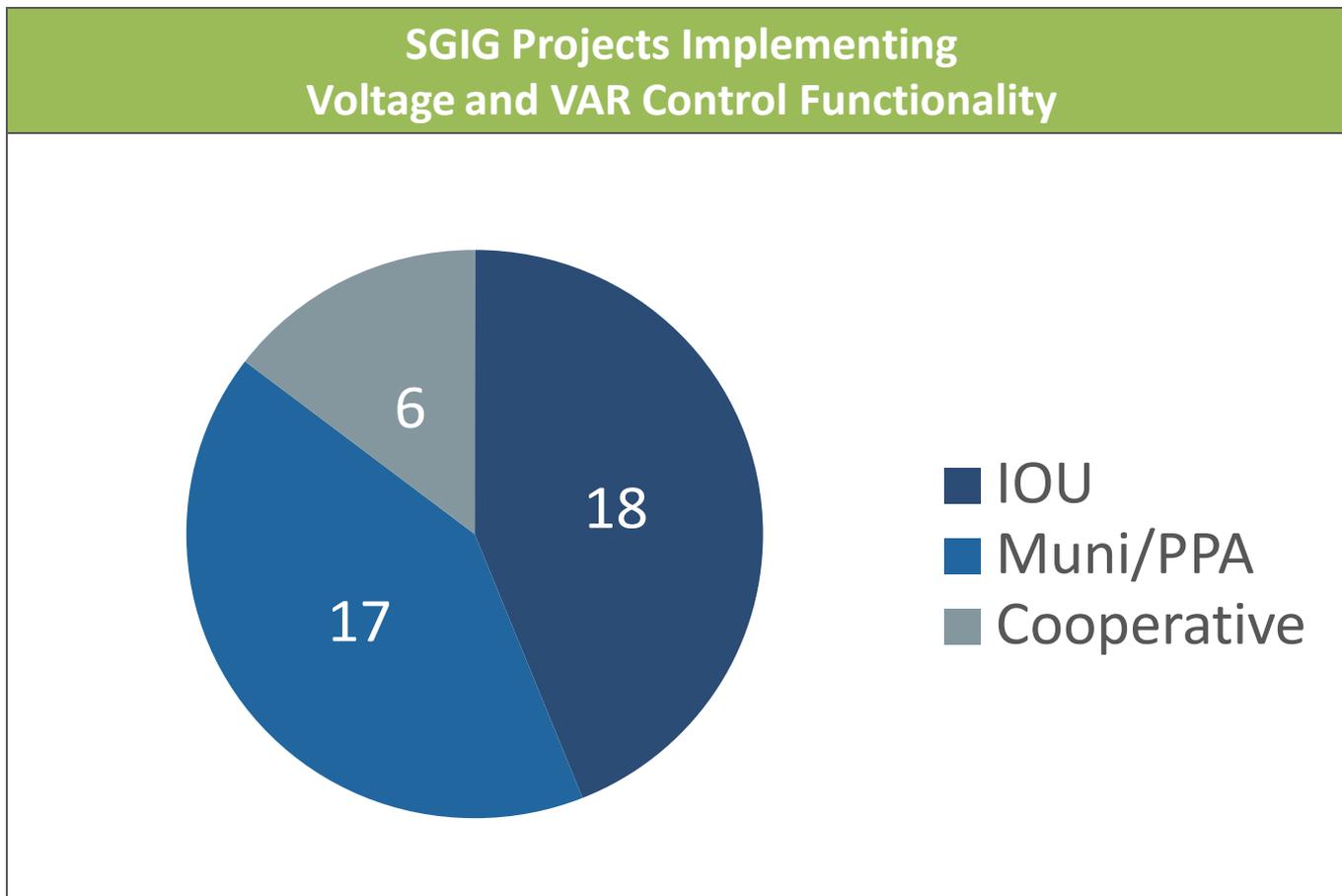
## Analysis Objectives

- Determine the improvement in energy efficiency from the application of technology used to optimize circuit voltage and implement conservation voltage reduction.
- Determine what technology configurations are most important for delivering measurable results.
- Quantify the value of energy and capacity savings for utilities, electricity savings for customers, and lower emissions.



# SGIG Projects

SGIG projects deploying voltage and VAR control functionality include a broad mix of IOUs, municipal and cooperative utilities.



Source: SGIG Build metrics and Navigant analysis



# Technologies

Project teams are deploying a variety of different technologies.

Line voltage sensor



Automated Capacitor Bank



Control package



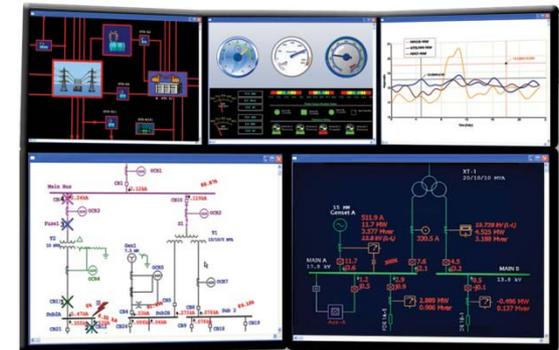
Smart meter



Automated Voltage Regulator



Distribution Management System





# Applications for Distribution Energy Efficiency

DOE has seen three general applications within projects that are conducting smart grid projects related to distribution energy efficiency.

## Voltage and VAR Control (VVC)

Operating transformer load tap-changers, line voltage regulators and/or capacitor banks to adjust voltage along a distribution circuit and/or compensate load power factor.

## Voltage Optimization (VO)

Coordinating VVC devices to achieve voltage profiles that meet the utility's operational objectives, including energy delivery efficiency, power quality, and reliability.

## Conservation Voltage Reduction (CVR)

Utilizing VVC and VO functionality to lower distribution voltages for energy savings, without causing customer voltages to fall below minimum operating limits.



# Build and Impact Metrics

Build and Impact metrics will track the deployment of technology and how it affects distribution load and energy efficiency.

## Build Metrics (Technologies)

- Automated capacitors
- Automated regulators
- Distribution circuit monitors or SCADA
- Distribution Management Systems (DMS)
- DMS integration with Advanced Metering Infrastructure
- Others
  - CVR algorithms
  - Load balancing
  - Reconductoring

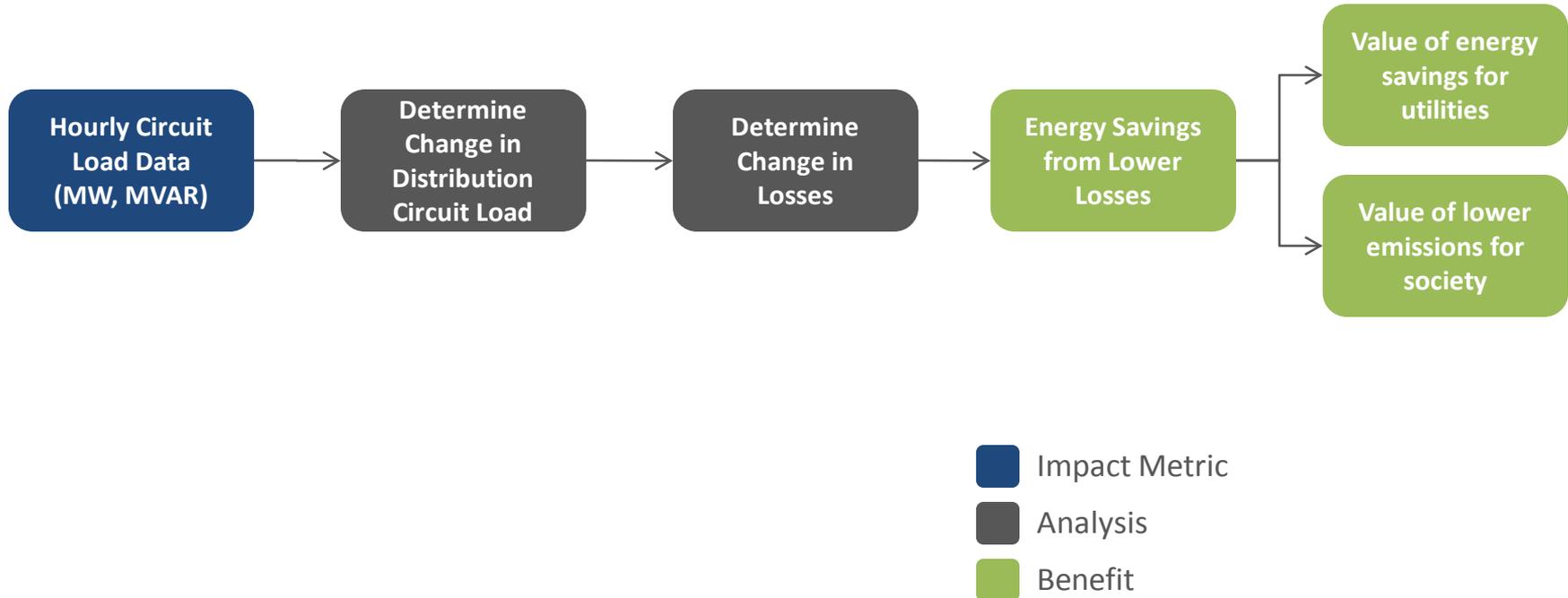
## Impact Metrics

- Distribution feeder load (hourly and/or average)
- Distribution power factor (hourly and/or average)
- Distribution losses (average/peak, % of load, or MWh for reporting period)
- Emissions reductions from energy savings
- Energy savings from CVR



# Logic for Analyzing Losses

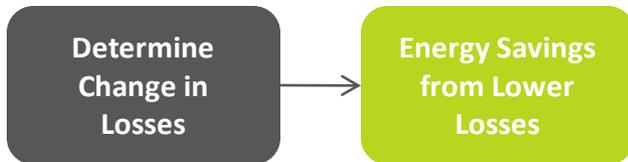
Analyzing the change in hourly circuit load can contribute to determining how much energy is saved by reducing distribution losses.





# Lower Losses The Meaning of Line Losses

Energy is wasted as electricity flows through distribution lines. This wasted energy is known as “line losses”.



Modern overhead distribution conductor is typically made of stranded aluminum wire, sometimes with a steel reinforcing core.

The resistance ( $R_L$ ) of the conductor is about 0.3 ohms per mile, and decreases with cross sectional area.

As line current flows through the conductor, its resistance dissipates power in the form of “line losses”.



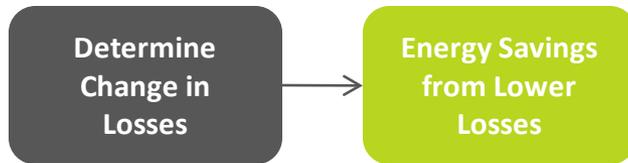
$$P_{\text{line losses}} = I_L^2 R_L \text{ watts}$$

*Higher line current means higher line losses, and vice versa*

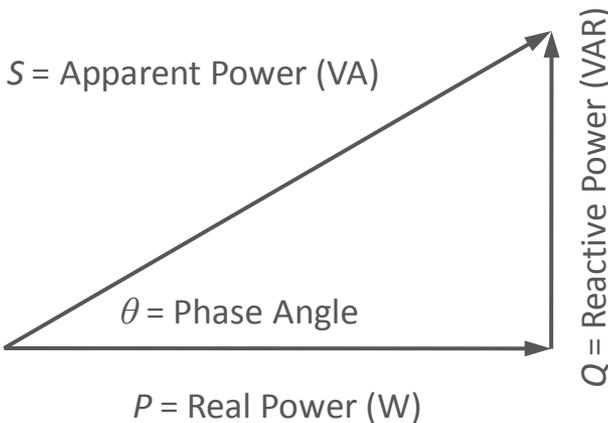


# Lower Losses Energy Savings from P/Q Data

Hourly data for real and reactive power will determine hourly line losses, and the difference between baseline and impact losses yields energy savings.



Some projects will be reporting hourly circuit load data for real (P) and reactive (Q) power. Using this information we will calculate hourly values for apparent power ( $S_{3\theta}$ ) and power factor, and then calculate hourly line current ( $I_L$ ):



$$I_L = \frac{S_{3\theta}}{\sqrt{3}V_{LL}} \text{ amperes}$$

With  $I_L$  and an assumption of distribution conductor resistance ( $R_L$ ), we calculate hourly line losses ( $P_{line\ losses}$ ):

$$P_{line\ losses} = I_L^2 R_L \text{ watts}$$

For each six-month reporting period (4380 hours) the total line losses per circuit or circuit group are:

$$S_{3\theta} = \sqrt{P_{3\theta}^2 + Q_{3\theta}^2} \text{ volt- amperes}$$

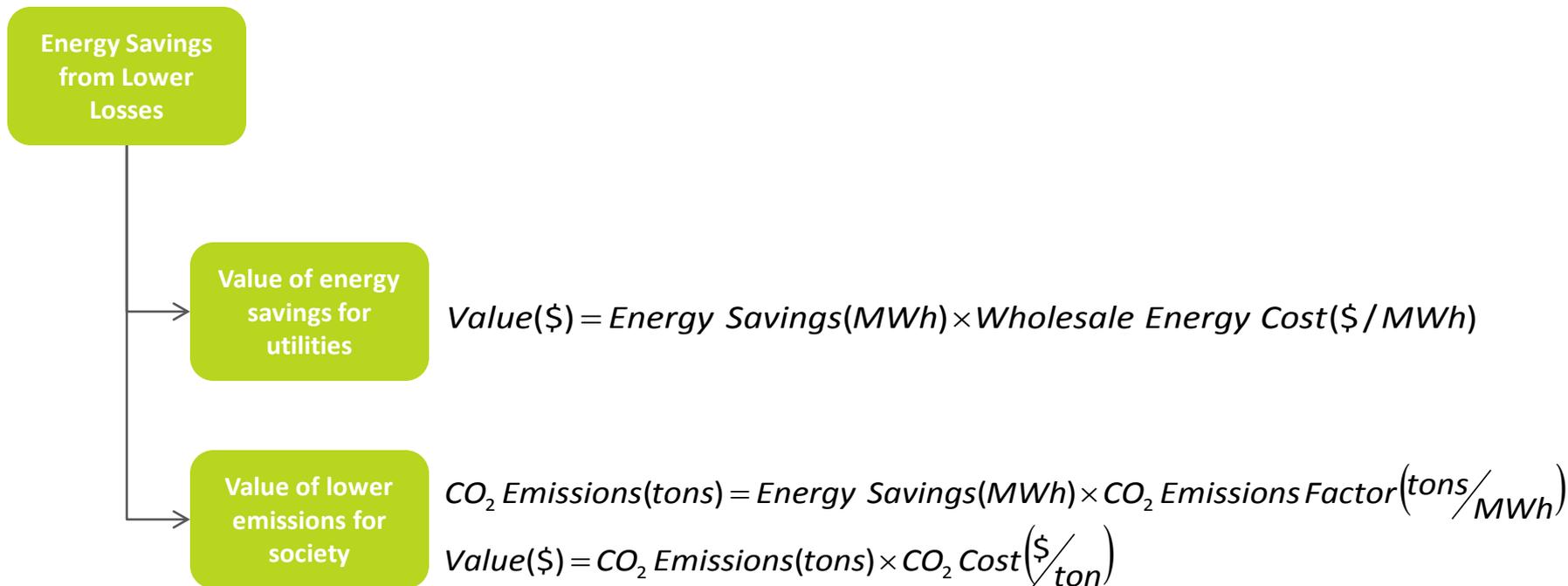
$$\text{power factor} = \cos^{-1}(\theta) = \frac{P_{3\theta}}{S_{3\theta}}$$

$$\text{Energy Savings} = \sum_{n=1}^{4380} P_{baseline} - \sum_{n=1}^{4380} P_{project} \text{ watt-hours}$$



# Lower Losses Value of Benefits

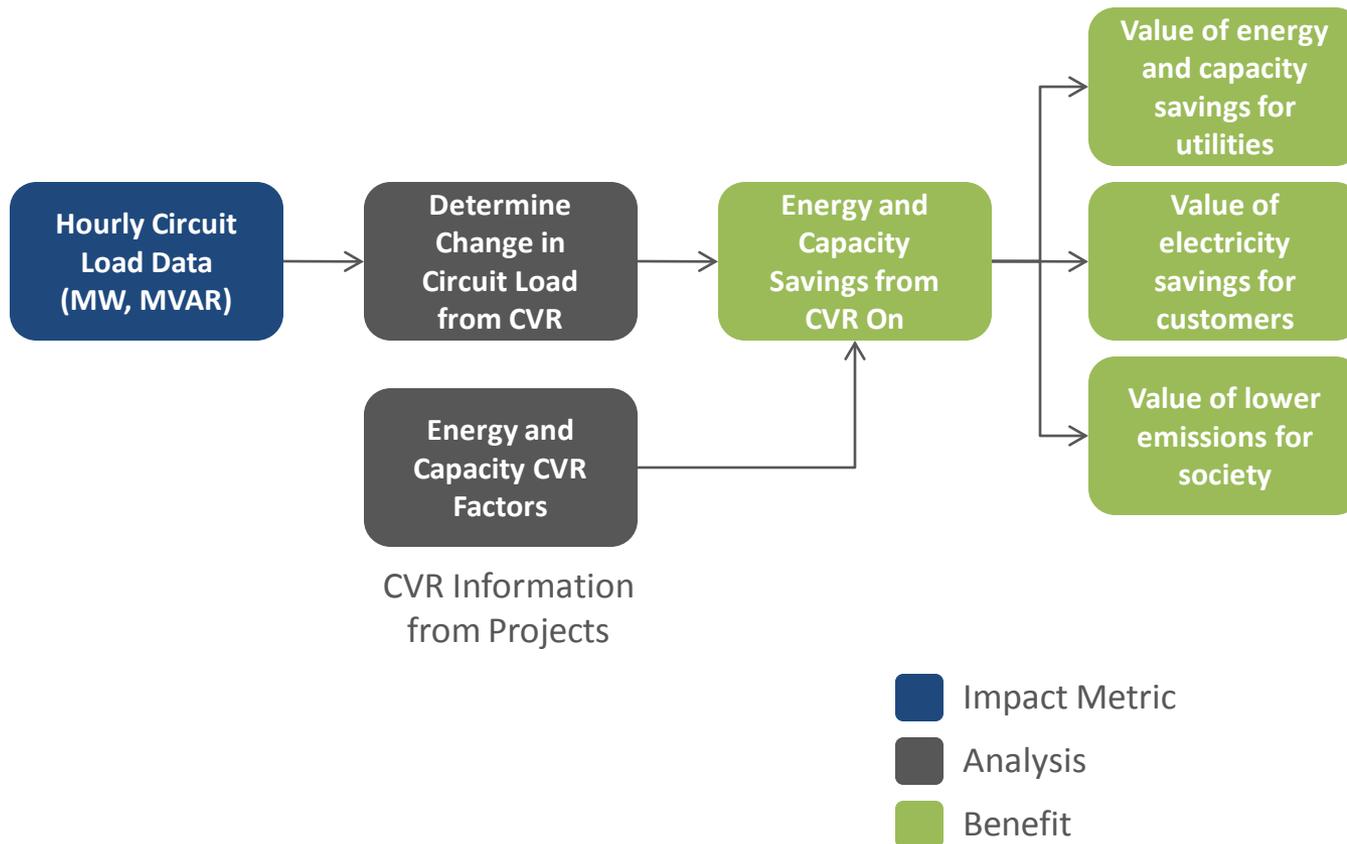
The energy savings from lower distribution losses saves utilities money on wholesale energy, and reduces carbon emissions and their potential cost.





# Logic for Analyzing CVR

We will work closely with projects implementing CVR to determine how implementation is creating energy and capacity savings.



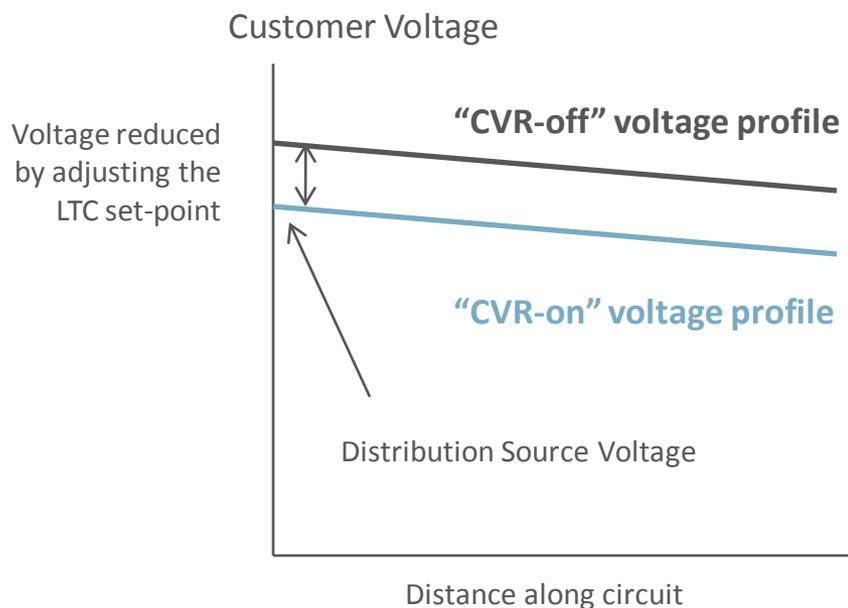


# Savings from CVR

## The Meaning of CVR

Conservation voltage reduction (CVR) reduces customer voltages along a distribution circuit to reduce electricity demand and energy consumption.

Energy and  
Capacity CVR  
Factors



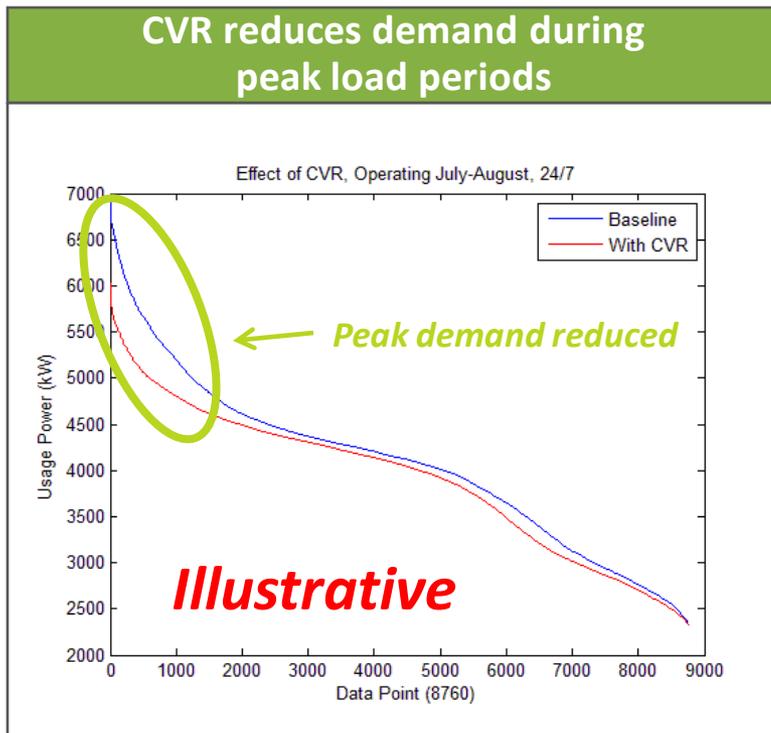
Studies dating back to the 1980s have shown that small reductions in distribution voltage can reduce electricity demand from customer equipment and save energy. This has become known as “conservation voltage reduction (CVR)”.

Recent utility pilot programs have demonstrated that lowering distribution voltage by 1% can reduce demand and energy consumption by 1% or more.



# Correlating CVR Results with Technology Configurations

By analyzing hourly load data and talking with utilities, we will try to correlate CVR factors with VVC technology configurations.



Source: Illustrative results from Navigant analysis

Some projects who are pursuing CVR will be reporting hourly circuit load data. By analyzing this data we hope to determine how much demand and energy savings each project achieves with its technology configuration.

CVR Factor ( $CVR_f$ )

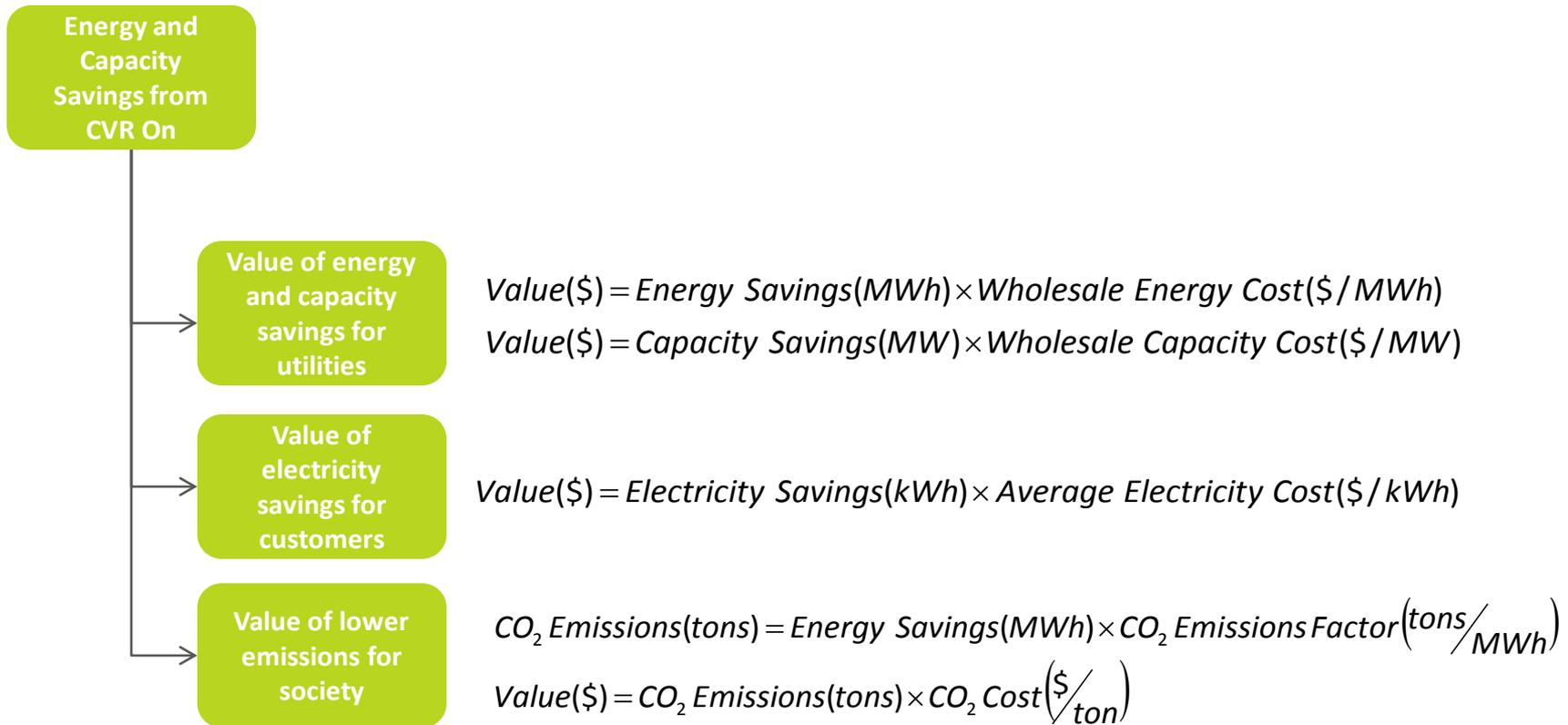
$$CVR_f = \frac{\Delta P}{\Delta V} \text{ watts/volt}$$

We will work with project teams in the focus group to understand how much distribution voltage was reduced to achieve the reduction in load.



# Savings from CVR Value of Benefits

The energy savings from CVR saves utilities and their customers money on energy and capacity, and reduces carbon emissions.





# Additional Analytical Questions

- What other kinds of impacts are project teams expecting, and how should we be looking for them in the metrics data?
- What other kinds of data or information can be shared to help the group understand impact?
- How are utilities operating the voltage and VAR control equipment and systems, and how can that shared?
- How are baselines and control group circuits being established?
- How might circuit topology and configuration affect results?
- What kinds of “experiments” can the forum projects perform together?